

Local variability of serotinous cones in a Canary Island pine (*Pinus canariensis*) stand

Unai López de Heredia¹, Rosa Ana López¹, Paula Guzmán¹, Nikos Nanos¹, Eduardo García-del-Rey², Pascual Gil Muñoz³, Luis Gil¹

¹ Forest Genetics and Physiology Research Group. E.T.S. Forestry Engineering. Technical University of Madrid (UPM). Ciudad Universitaria s/n. 28040. Madrid, Spain

² Departamento de Ecología, Facultad de Biología, Universidad de La Laguna, 38206 La Laguna, Tenerife, Canary Islands, Spain

³ Sección de Montes, Medio Ambiente, Cabildo Insular de Tenerife, Santa Cruz de Tenerife 38200, Canary Islands, Spain

The endemic Canary Island pine (*Pinus canariensis*) has an effective strategy to counteract fire disturbance in the short term. It has a mixed strategy that combines the presence of serotinous cones and thick barks with the ability to re-sprout from the trunk after a fire, a rare trait in pine species. High frequency of fires in the Canary Islands is related to human action, as natural fires by lightning or vulcan activity have very low frequency; hence, the how and whys of the presence of serotinous cones in the species is still a topic of debate. Previous studies showed that the frequency of serotinous cones varies from stand to stand. Here, we analyzed the presence of serotinous cones at a local scale. We selected a Canary Island pine stand in the transition zone between dry and humid forests in the south of Tenerife. Branches were pruned from 20 trees in order to evaluate the presence of serotinous vs. non-serotinous cones by direct verticle counting on the branches. The opening temperature of serotinous cones was assessed in the laboratory. Percentages of serotinous vs. non-serotinous cones varied from 0 to 93 %, showing high variability between trees. Opening temperatures were very high (above 65 °C) as compared to other Mediterranean pine species with serotinous cones.

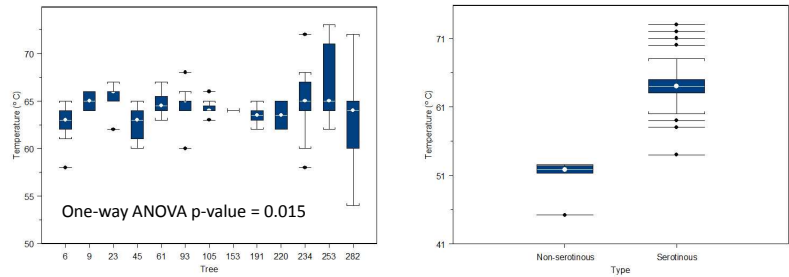
Introduction

Serotiny is a common trait in Mediterranean pine species (Tapias et al. 2001). Serotinous cones are those that remain closed stored in the canopy (Lamont1991). The endemic Canary Island pine (*Pinus canariensis*) shows a variable percentage of serotiny depending on the ecological region, being annual rainfall a determinant of the presence of serotinous cones. The percentage of serotinous cones in humid pinewoods with understory of *Myrica faya* and *Erica arborea* is higher than in dry pinewoods of southern slopes (Climent et al. 2004). Here we analyzed the opening temperature of serotinous and non-serotinous cones in the transition area between humid and dry pinewood to evaluate the local variability of this trait and compare it with the opening temperature in other serotinous Mediterranean pine species. Then, we discuss the presence of serotiny in Canary Island pine in light of active volcanism in the islands.



Material and Methods

We selected a population in the transition area between humid and dry pinewoods in Tenerife (Chirigel, 28°25' N, 16°23' W, elevation: 1100 m) with an understory of *Myrica faya* and *Erica arborea*. A strong fire took place in 1995 depleting all the seedlings and understory species installed before that date. Branches were pruned from 20 trees sampled randomly in order to evaluate the percentage of serotinous vs. non-serotinous cones by direct verticle counting on the branches. Percentage of serotiny was evaluated. The opening temperature of serotinous cones and of a sub-sample of non-serotinous cones was assessed following a protocol based on that of Perry and Lotan (1977). First, cones were dried at 30° C. Then, cones were individually submerged in a water bowl and temperature was progressively increased. Cone opening was accompanied by the emission of bubbles and an audible "crack" as the scales separated abruptly.



Results and Discussion

455 closed cones were collected in the 20 trees from Chirigel. As expected, the selected population showed a high percentage of serotinous cones (70%). 14 out of 20 trees had serotinous cones considering only presence or absence. Within the trees showing serotinous cones, the degree of serotiny estimated as the ratio between serotinous and non-serotinous cones was highly variable in the population (0.05-0.93). The opening temperature of serotinous cones estimated under water was variable between trees within the population. Opening temperature varied significantly between serotinous (64.1 ± 3.0° C) and non-serotinous cones (50.9 ± 2.8° C). These opening temperatures for serotinous cones are also significantly higher than those from other Mediterranean pines such as *Pinus pinaster* (45.8 ± 0.8° C) and *Pinus halepensis* (50.7 ± 0.4° C). This suggests differences in the resin seals' composition, and possibly different 'leit motifs' for serotiny in Canary Island pine in comparison to other Mediterranean pines.

id tree	Non-Serotinous	Serotinous	Ser/NonSer	Ser/Total
35	8	0	0,0	0,00
61	1	13	13,0	0,93
9	7	12	1,7	0,63
23	19	5	0,3	0,21
6	6	13	2,2	0,68
127	18	0	0,0	0,00
234	9	12	1,3	0,57
45	21	11	0,5	0,34
87	5	0	0,0	0,00
288	3	1	0,3	0,25
105	7	7	1,0	0,50
93	14	20	1,4	0,59
149	26	0	0,0	0,00
239	10	0	0,0	0,00
282	3	27	9,0	0,90
253	2	13	6,5	0,87
331	11	0	0,0	0,00
153	4	1	0,3	0,20
220	18	3	0,2	0,14
191	119	6	0,1	0,05
Total	311	144	0,5	0,32

P. canariensis
64.2 ± 2.8° C
P. halepensis
50.7 ± 0.4° C
P. pinaster
45.8 ± 0.8° C

Opening temperature of serotinous cones of three Mediterranean pines. *Pinus canariensis* shows the highest opening temperatures

Percentage of serotinous and snon-serotinous trees in the population of Chirigel

Opening temperature of serotinous cones is divergent between trees

Opening temperature of serotinous and non-serotinous cones

Serotiny and volcanism

Two main types of serotinous cones can be described: 1) pyriscent cones, i.e. those that open after a fire; 2) xeriscent cones, i.e. those that simply remain in the canopy and open after a variable period of drying. Canary Island pine cones are thought to be xeriscent (Nathan et al. 1999; Climent et al. 2004), but at the same time, they are invoked as a strategy to counteract fire (Climent et al. 2004). However, the time period during which fire of anthropogenic origin became a major force in the Canary Islands is too short for the selection and radiation of new traits in long-living organisms such as Canary Island pine. Moreover, in a fire-prone environment, serotiny is advantageous only when post-fire conditions are optimal (Lamont and Enright 2000), which is not the case for Canary Island pine. After a fire, a dense cohort of regeneration seedlings establish in the understory (Rüdiger et al. 2010), but this cohort has not future because fire does not kill adult pines, which are able to re-sprout, hence it does not generate gaps and seedlings will not incorporate to the adult cohort.

We propose that active volcanism rather than fire is the selective force that has induced serotiny in Canary Island pine. After a volcanic eruption, in those areas where the depth of pyroclast sediments is less than tree height, pyroclast rains would cover up the understory but enabling survival of the adult pines, as reported for Gran Canaria (Anderson et al. 2009). Then, seeds released from serotinous cones will colonize newly generated salic substrates by lava flows. Recurrence of volcanic episodes supports this hypothesis. Historical records show 22 volcanic events from 1430 to 1971, in a no particular volcanic period. We hypothesize a sufficient recurrence period for the development of the serotinous trait in other stages with active volcanism, such as in the development of the Cañadas complex (2-0.5 my BP) (Carracedo 2007).

Cause	Nº	Fires		Forest Surface	
		%		Total (ha)	%
Lightning	10	0.5	16.84	0	
Negligencies	580	30.6	18049.9	25	
Intentional	633	33.4	45951.9	63.6	
Unknown	661	34.9	8231.2	11.4	
Replica	10	0.5	3.3	0	
Overall 1983-2007	1894	100	72253	100	

Number of fires and forest surface listed by cause in Tenerife in the period 1983-2007



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